CLAIMS

What is claimed is:

1. A method of modeling failure of a borehole in a subsurface formation, the method comprising:;

(a) defining a subsurface model including a plurality of regions, said plurality of regions including the borehole and at least one additional region selected from (i) a liner in the borehole, (ii) a casing in the borehole, and (iii) at least one earth formation , each of said plurality of regions comprising a plurality of nodes interconnected by a plurality of linkages,

(b) defining material properties associated with said nodes and said linkages of said subsurface model, said material properties having a statistical variation;

(c) specifying an initial deformation pattern of the model; and

(d) using a dynamic range relaxation algorithm (DRRA) to find a force equilibrium solution for said subsurface model and said initial deformation pattern giving a resulting deformed model including fracturing.

2. The method of claim 1, wherein said nodes are arranged in a grid that is one of (i) a triangular grid, and, (ii) a random grid.

3. The method of claim 1 wherein said linkages are selected from the group consisting of (A) springs, (B) beams, and. (C) rods.

4. The method of claim 1 wherein said linkages comprise springs, the method further comprising defining a normal force associated with each spring.

5. The method of claim 1 wherein said linkages comprise beams, the method further comprising defining at least one of (A) a normal force, and (B) a shear force associated with each beam.

6. The method of claim 1 wherein said linkages comprise rods, the method further comprising defining at least one of (A) a normal force and (B) a force associated with an angle between pairs of said adjacent ones of the plurality of rods.

7. The method of claim 1, wherein using the dynamic range relaxation algorithm further comprises applying said initial deformation model in a plurality of steps, each step comprising applying a specified fraction of the initial deformation and determining if any linkages between the nodes have been deformed beyond a breaking point and identifying a subset of the linkages that have been so deformed.

8. The method of claim 7, wherein applying the dynamic range relaxation algorithm further comprises iteratively breaking the one linkage of the subset of linkages that has been deformed the most and applying a relaxation algorithm to the remaining unbroken linkages.

9. The method of claim 9 wherein the at least one earth formation further comprise a near earth formation including a gravel pack and a far earth formation.

10. The method of claim 1 wherein the plurality of regions comprises a liner in the borehole, an earth formation including a near earth formation and a far earth formation, and a gravel pack disposed between the liner and the near earth formation.

11. The method of claim 1 wherein said linkages connect at least one selected node of said plurality of nodes with (i) a plurality of nearest neighbors of the at least one selected node, and (ii) a plurality of next nearest neighbors of the at least one selected node.

12. The method of claim 1 wherein said earth formations include a fluid, said fluid flowing into the borehole, and said deformation pattern is determined in part by a decrease in formation fluid pressure resulting from flow of said fluid into the borehole.

13. The method of claim 12 wherein using the DRRA further comprises determining an additional force at each node related to a difference in said fluid pressure on opposite sides of at least a subset of the plurality of nodes.

14. The method of claim 13 wherein determining said additional force further comprises performing a simulation selected from (i) a finite difference simulation, and, (ii) a finite element simulation, of said fluid flow.

15. The method of claim 14 wherein performing said simulation further comprises changing at least one of (A) a permeability, and, (B) a porosity used in said simulation responsive to said deformation.

16. The method of claim 1 wherein said borehole includes a substantially vertical section wherein said initial deformation pattern is substantially azimuthally symmetric about an axis of the borehole in said section.

17. The method of claim 16 wherein said borehole includes a deviated section wherein said initial deformation pattern is asymmetrical about an axis of the borehole.

18. A method of modeling failure of a borehole in a subsurface formation, the method comprising:

(a) defining a subsurface model having a plurality of nodes and including a plurality of regions, said plurality of regions including the borehole and at least one additional region selected from (i) a liner in the borehole, (ii) a casing in the borehole, and (iii) at least one earth formation, each of said plurality of regions comprising a plurality of nodes interconnected by a plurality of linkages,

(b) defining material properties associated with said nodes and said linkages of said subsurface model, said material properties having a statistical variation;

(c) specifying a force distribution applied to the model at boundary nodes of said plurality of nodes; and

(e) using a dynamic range relaxation algorithm (DRRA) to find a force equilibrium solution for said subsurface model and said force distribution giving a resulting deformed model including fracturing.

19. The method of claim 18 wherein the subsurface formation has been subjected to large scale geologic deformation and wherein specifying said force distribution further comprises:

(i) simulating the large scale geologic deformation to determine a stress distribution in the subsurface formation in the absence of the borehole,

(ii) defining a trajectory for the borehole therein, and

(iii) identifying locations along said trajectory that are likely to fail.

20. The method of claim 18 wherein the forces can vary between the boundary nodes.

21. The method of claim 19 wherein identifying said trajectories further comprises removing a plurality of nodes along said trajectory.

22. The method of claim 18, wherein said nodes are arranged in a grid that is one

of (i) a triangular grid, and, (ii) a random grid.

23. The method of claim 18 wherein said linkages are selected from the group consisting of (A) springs, (B) beams, and. (C) rods.

24. The method of claim 18 wherein said linkages comprise springs, the method further comprising defining a normal force associated with each spring.

25. The method of claim 18 wherein said linkages comprise beams, the method further comprising defining at least one of (A) a normal force, and (B) a shear force associated with each beam.

26. The method of claim 18 wherein said linkages comprise rods, the method further comprising defining at least one of (A) a normal force and (B) a force associated with an angle between pairs of said adjacent ones of the plurality of rods.

27. The method of claim 18, wherein using the dynamic range relaxation algorithm further comprises applying said force distribution in a plurality of steps, each step comprising applying a specified fraction of the force and determining if any linkages between the nodes have been deformed beyond a breaking point and identifying a subset of the linkages that have been so deformed.

28. The method of claim 27, wherein applying the dynamic range relaxation algorithm further comprises iteratively breaking the one linkage of the subset of linkages that has been deformed the most and applying a relaxation algorithm to the remaining unbroken linkages.

29. A method of modeling faulting and fracturing in a subsurface volume of the earth comprising:

(a) defining said subsurface model including a plurality of interconnected nodes and material rock properties within the subsurface volume;

(b) specifying a stress distribution at a subset of said plurality of nodes, said subset comprising boundary nodes; and

(c) using a dynamic range relaxation algorithm to find a force equilibrium solution for said subsurface model and said stress distribution giving a resulting deformed model including fracturing.

30. The method of claim 29, wherein defining a subsurface model, and specifying said stress distribution further comprises using a graphical user interface.

31. The method of claim 29, wherein said nodes are arranged in a grid that is one of (i) a triangular grid, and, (ii) a random grid.

32. The method of claim 29, wherein said nodes are interconnected by linkages selected from (i) springs, (ii) beams, and, (iii) rods.